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EXPERIMENTS FOR THE CONTROL OF THE SAN JOSE SCALE WITH LUBRICATING-OIL EMULSIONS IN THE PACIFIC NORTHWEST

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INTRODUCTION

The San Jose scale (*Aspidiotus perniciosus* Comstock) has been gradually increasing in many parts of the Pacific Northwest, until the loss of fruit caused by this pest has become very noticeable. This increase has not been due to a failure of the lime sulphur to kill the scale, although there may be particular cases where this has occurred. It has been due chiefly to an increasing carelessness in applying the spray. The trees are becoming larger and more difficult to spray, the spray guns generally used are sometimes handled improperly, and men of the type employed for this kind of work appear less inclined to be thorough than formerly. There have also been orchards in which the customary annual dormant application has been omitted for one or more years, in consequence of which these orchards have become seriously infested with the scale, the infestation spreading to the surrounding orchards.

The successful use of lubricating-oil emulsions against the San Jose scale in the Middle West a number of years ago, in place of lime sulphur, greatly increased the popularity of oil sprays in the West. For this reason, and because of the increase in the scale, a series of tests was made by the Bureau of Entomology at Yakima, Wash., in order to find out whether a lubricating-oil emulsion could replace lime sulphur as a scale spray and, if so, at what strength it must be used.

Lime sulphur, while very effective, has several drawbacks. It is bulky and is disagreeable to handle on account of its caustic effect on the face and hands. A few drops of spray in the eyes of the

operator often blind him temporarily, and he fails to cover thoroughly all parts of a tree. Lime sulphur, at the usual strength for dormant trees, has little effect on the eggs of the red spiders, of tree hoppers, or of the fruit-tree leaf roller (*Archips argyrospila* Walk.), or on either the eggs or newly hatched young of aphids. If used in the spring, after the leaves are partly out, it sometimes causes a severe dropping of the fruit buds. Its cost is high where it has to be shipped to a distance.

The oil sprays are more concentrated, and are cheaper and more easily handled than lime sulphur. They are not so caustic, and they allow the operator to see what he is doing at all times. If used after the buds have started to open, they are more apt to cause injury than the lime sulphur, and they should therefore be used before the buds open. If used at the proper strength, oil sprays control the San Jose scale very effectively, and they also result in a very good control of tree hoppers, red spiders, and aphids. Oil sprays must be used for the eggs of the fruit-tree leaf roller. They are not very effective against the peach twig borer (*Anarsia lineatella* Zell.), and are less effective than lime sulphur against the pear-leaf blister mite (*Eriophyes pyri* Pgst.).

The danger of injury to dormant trees from oil sprays is very slight. Trees in this condition have been commonly sprayed in the Pacific Northwest for a number of years, with no apparent ill effects. Even where an improperly prepared emulsion was used, which contained some free oil, the injury to dormant apple trees was of little consequence. Dormant prune trees have sometimes been killed, however, by applications of oil sprays containing free oil. Oil sprays have been used for 4 or 5 years in the Spokane Valley of Washington for the control of the fruit-tree leaf roller, and have been used against this insect for 12 or 14 years in the Hood River Valley of Oregon. Although it is necessary to use the oil emulsion nearly twice as strong for the leaf roller as for the scale, no injury has been evident where the oil was properly applied. Very cold weather following the application of oil sprays in the fall has resulted in injury, and occasionally has killed the trees. No injury has occurred, however, from cold weather following dormant spraying in the spring. The usual frosty nights experienced in March and April have not resulted in injury to oil-sprayed trees. Even temperatures below zero, following an early February application of oil, have not affected the trees.

A large amount of injury has resulted from the application of lubricating-oil sprays to dormant trees after the buds have started to open. This was especially true in 1925 when, on account of a very early spring, a great deal of spraying was done after the buds had separated, and even after some of the blossoms had opened. Used at this time, oil sprays will cause more damage than lime sulphur, although the latter will also result in much injury. Oil sprays, when used at strengths suitable for dormant trees, should be used only when the trees are practically dormant; that is, before the bud scales have separated.

This circular covers work done at Yakima, Wash., during the seasons of 1923, 1924, 1925, and 1927. Experiments were carried out both in the laboratory and in orchards.

SPRAYING EXPERIMENTS IN 1923

A few tests of oil sprays were made in 1923, and scales were examined from several orchards sprayed by various growers. The results of these examinations did not indicate that the 2 per cent emulsion could be depended on to control the scale. In two tests, slightly over 99 per cent of the scales were dead, but in the others the percentages killed ranged from 93 to 97. In even moderately infested orchards, more than 99 per cent of the scales must be killed to effect satisfactory control.

It was found that the soap emulsions used in the East were very likely, in the Pacific Northwest, to break down in the hard water available for spraying. At the time the dormant spray is applied in the Yakima Valley, water has usually not been turned into the irrigation canals, and water for spraying must be secured from drainage ditches, wells, or cisterns. These waters are very hard, containing large quantities of calcium bicarbonate, magnesium bicarbonate, and sodium sulphate. Even the irrigation water is usually somewhat too hard for use with the soap emulsions. Table 1 gives an analysis of several samples of water, and shows the difference between irrigation water and the well water and drainage water. These samples were collected in February, 1924, shortly before the spraying season started.

TABLE 1.—*Analyses of waters used for spraying in the Yakima Valley, Wash., February, 1924* [1]

Constituents	Irrigation water, Yakima	Well water, Grandview [2]	Drainage water, Granger [2]
	Parts per million	*Parts per million*	*Parts per million*
Total solids	59.8	891.6	1,184.3
Calcium (Ca)	7.8	44.5	51.4
Magnesium (Mg)	2.0	110.9	43.7
Bicarbonate radicle (HCO_3)	62.0	147.0	340.7
Sulphate radicle (SO_4)	2.6	77.0	321.1
Sodium (Na)	22.3	106.4	229.5

[1] These analyses were made by E. L. Green, formerly assistant chemist, Washington Agricultural Experiment Station.

[2] These analyses are evidently incomplete, and it is suggested that chlorides were present but not determined.

The large quantities of calcium and magnesium salts present in the well and drainage waters decompose most of the potassium soap in the oil emulsion, allowing the oil droplets to run together and come to the surface as free oil. It is also probable that a certain amount of inversion takes place. The calcium or magnesium soap formed is more soluble in oil than in water; hence the oil-in-water emulsion is changed to some extent to a water-in-oil emulsion which will not mix with water. The decomposition of the soap is hastened by the stirring of the dilute emulsion in the spray tank with the agitator. Even without this agitation the emulsion is partially broken down before it can be used.

Soft water was used in the two tests mentioned above in which less than 1 per cent of the scale survived, but in the others the water was hard, and it was thought that this may have made the difference in the control obtained.

SPRAYING EXPERIMENTS IN 1924

A large series of spraying tests was made against the San Jose scale in the spring of 1924. It was evident from the experience of 1923 that the boiled lubricating-oil emulsion, made with potash fish-oil soap, can not be recommended for use in the Pacific Northwest, except where soft water is available. Attempts to remedy the difficulty by the use of stabilizers, such as more soap, flour, glue, casein, weak Bordeaux mixture, and cresol, were not very successful. The hard water can be softened by adding lye to it and allowing it to stand for a day or two, but this is impracticable, as the growers do not have storage tanks.

It was known that various commercial miscible oils made of lubricating or fuel oils, soap, and cresylic acid (cresol) mixed with hard water much more readily than did the boiled lubricating-oil emulsion. The possibility of making a "homemade" miscible oil was therefore investigated during the winter of 1923–24, and a method was worked out which is given on page 10. It was found that this miscible oil could be made without any pumping and with very little or no heating. To be perfect, however, the various ingredients must be measured out accurately, and since the soap obtainable always contains some water, this water content must be known. This soap is not ordinarily sold with any guaranty as to water content, and it is subject to drying if exposed to the air. It is therefore difficult for an individual grower to make this miscible oil.

A cheaper and more easily made oil spray than the miscible oil is one that originated at the Missouri Experiment Station.[1] In making this emulsion the oil is emulsified by means of calcium caseinate (casein spreader). This emulsion may be called the "caseinate oil emulsion." It has the advantages of being cheaply and easily prepared by anyone capable of following simple directions, and also of mixing perfectly with any hard water and even with lime sulphur. It should be made up as needed, for it will not keep very well for more than a week or two.

In the tests made in 1924 lubricating-oil emulsions made with soaps and with casein spreader were used, as well as the miscible oil and commercial lime sulphur. The spray was applied with a bucket pump to limbs of trees infested with the San Jose scale. Twigs from these limbs were examined with a binocular microscope about a month after the spray was applied, and a record was made of the percentage of the scales that were dead, only the half-grown female scales being considered. The results obtained are presented in Table 2, and the percentage of control is also given. This has been figured in accordance with the method used by Abbott, Culver, and Morgan.[2]

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[1] BURROUGHS, A. M. A NEW METHOD OF MAKING ENGINE OIL EMULSIONS. Missouri Agr. Expt. Sta. Bul. 205, 8 p., illus. 1923.

[2] ABBOTT, W. S., CULVER, J. J., and MORGAN, W. J. EFFECTIVENESS AGAINST THE SAN JOSE SCALE OF THE DRY SUBSTITUTES FOR LIQUID LIME-SULPHUR. U. S. Dept. Agr. Bul. 1371, p. 6. 1926.

TABLE 2.—*Results of experiments with lubricating-oil and lime-sulphur sprays on the San Jose scale on apple trees, Yakima, Wash., 1924*

[Approximately 1,000 scales examined in each test]

No.	Material used	Dilution	Tests made	Scales dead	Control
		Per cent oil	*Number*	*Per cent*	*Per cent*
1	Lubricating-oil (red engine)[1] emulsion (soap emulsifier)[2]	2	6	98.2	97.8
2	Do	3	1	99.6	99.5
3	Do	4	1	99.9	99.9
4	Lubricating-oil (brown neutral)[3] emulsion (soap emulsifier)[2]	2	6	96.7	95.9
5	Do	3	1	99.5	99.4
6	Lubricating-oil (brown neutral)[3] emulsion (casein emulsifier)[4]	2	6	95.4	94.2
7	Do	3	3	99.6	99.5
8	Miscible oil[5] (brown neutral oil)[4]	2	7	96.3	95.4
		°*B.*			
9	Commercial lime sulphur, 32° Baumé	4	2	95.8	94.8
10	Do	5	2	93.7	92.2
11	Check		6	19.1	

[1] See specification No. 8 (p. 11).
[2] See formula No. 1 (p. 9).
[3] See specification No. 6 (p. 11).
[4] See formula No. 2 (p. 9).
[5] See formula No. 3 (p. 10).

While Table 2 indicates that better control was obtained with the 2 per cent oil sprays than with the lime sulphur, from 2 to 4 per cent of the scales survived, and this is too large a percentage for effective control. Although lime sulphur allows a small percentage of scales to survive, it was found that these frequently do not reproduce, even though they may live until the middle of the summer.[3] This applies only to the scales that have been actually covered with the spray and have survived. Those not sprayed reproduce as usual. This does not seem to be the case with oil-sprayed scales; hence with oil it is necessary to approximate 100 per cent kill of the scale in order to control it. Of the 25 tests made with a 2 per cent oil, and recorded in Table 2, tests 1, 4, 6, and 8, only 7 were satisfactory. In these 7 less than 1 per cent of the scales survived, but on an average these tests allowed too many scales to live for good control. The few tests made with oils at greater strengths indicated that dilutions of 3 or 4 per cent would be sufficiently effective for good scale control. Little or no difference was evident in the effectiveness of the emulsions made with soap or with casein spreader and those made of the miscible oils. There is also very little difference in the effectiveness of the heavy (red engine) and light (brown neutral) oils.

At harvest time fruit was examined for scale in an orchard part of which had been sprayed, while the trees were dormant, with lime sulphur, part with a 2 per cent caseinate oil emulsion, and part with a 3 per cent caseinate oil emulsion. There had been a light infestation of the scale in the orchard, but the infestation was not sufficient to furnish counts in the spring. Three or four thousand apples were examined in each portion of the orchard. In the trees sprayed with lime sulphur 0.23 per cent of the apples were infested with the scale, in those sprayed with the 3 per cent caseinate oil emulsion 0.49 per cent of the apples were infested, and in those sprayed with the 2 per cent emulsion 1.36 per cent of the apples were infested. This indicates that the lime sulphur is effective, and also that the

[3] NEWCOMER, E. J., and YOTHERS, M. A. STERILITY IN THE SAN JOSE SCALE. Jour. Econ. Ent. 22: 821. 1929.

3 per cent oil spray is much more effective than the 2 per cent oil. The presence of a small amount of the scale in the first two blocks is probably due to a failure to cover the trees thoroughly in spraying, or to infestation that spread from other trees during the summer.

SPRAYING EXPERIMENTS IN 1925

In 1925 a series of experiments was made to test the comparative value of oil emulsions diluted to 2, 3, 4, 6, and 8 per cent of oil. A comparison was made, at the 2, 3, and 4 per cent strengths, of the cold-mixed caseinate oil emulsion, the boiled emulsion prepared with soap, and the miscible oil. The boiled emulsion used in these tests was prepared at the United States entomological laboratory at Fort Valley, Ga., and shipped to Yakima. A red engine oil having a Saybolt viscosity of 227 seconds was used. Brown neutral oil was used in making the caseinate emulsion and the miscible oil. This had a viscosity of 116 seconds. The other characteristics of these oils are given on page 11. These tests were made with a bucket pump, and the scales were examined about one month later. This series of experiments was carried out twice, once on February 24 and again on March 13. The results of the two series of tests were averaged and are given in Table 3.

TABLE 3.—*Results of experiments with lubricating-oil and lime-sulphur sprays on the San Jose scale on apple trees, Yakima, Wash., 1925*

[Approximately 1,500 scales examined in each test]

No.	Materials used	Dilution	Tests made	Scale dead	Control
		Per cent oil	*Number*	*Per cent*	*Per cent*
1	Lubricating-oil (brown neutral)[1] emulsion (casein emulsifier)[2]	2	2	90.3	80.8
2	Do	3	2	98.8	97.6
3	Do	4	2	99.6	99.2
4	Do	6	1	100.0	100.0
5	Do	8	1	100.0	100.0
6	Miscible oil [3] (brown neutral oil)[1]	2	2	91.3	82.8
7	Do	3	2	98.7	97.4
8	Do	4	2	99.7	99.4
9	Lubricating-oil (eastern red engine)[4] emulsion (soap emulsifier)[5]	2	2	91.4	83.0
10	Do	3	2	97.3	94.7
11	Do	4	2	99.1	98.2
		°*B.*			
12	Commercial lime sulphur, 28° Baumé	4	2	95.3	90.7
13	Check	--------	2	49.5	--------

[1] See specification No. 6. (p. 11).
[2] See formula No. 2 (p. 9).
[3] See formula No. 3 (p. 10).
[4] See specification No. 9 (p. 11).
[5] See formula No. 1 (p. 9).

Very little difference is evident in the three types of oil sprays. The results from the cold-mixed caseinate oil emulsion and from the miscible oil are practically identical. The boiled emulsion, prepared with soap, gave slightly poorer results than the others with the 3 and 4 per cent dilutions.

The emulsions used at a dilution of 2 per cent of oil gave rather poor results, 9 or 10 per cent of the scales remaining alive. At 3 per cent the results were much better, only 1 or 2 per cent of the scales surviving, while at 4 per cent less than 1 per cent of the scales survived. The 6 and 8 per cent dilutions of the caseinate oil emulsion resulted in a complete mortality of the scales. Lime sulphur at a dilution of 4° Baumé left about 5 per cent of the scales alive.

A test was also made in 1925 of the caseinate oil emulsion with and without additional casein spreader. The results, given in Table 4, are averages of two series of tests, one made on February 24 and the other on March 13. The tests without additional spreader are the same as tests 1, 2, and 3 in Table 3. For those with additional spreader some of the same diluted material was used, casein spreader being added to it at the rate of 1 pound to 100 gallons of spray. The results obtained from the three dilutions are rather variable. From these experiments it can not be said that the addition of the spreader either increases or decreases the effectiveness of the oil spray.

TABLE 4.—*Results of experiments with caseinate oil emulsions, with and without additional casein spreader, on the San Jose scale, Yakima, Wash., 1925*

[Approximately 1,000 scales examined in each test]

No.	Material used	Dilution	Tests made	Without additional spreader		With additional spreader	
				Dead	Control	Dead	Control
		Per cent oil	*Number*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	Lubricating-oil (brown neutral) [1] emulsion (casein emulsifier) [2]	2	2	90.3	80.8	91.5	83.2
2	Do	3	2	98.8	97.6	95.0	90.1
3	Do	4	2	99.6	99.2	99.6	99.2
4	Check	----	2	49.5	----	49.5	----

[1] See specification No. 6 (p. 11). [2] See formula No. 2 (p. 9).

Table 5 gives some results obtained with a combination of caseinate oil emulsion and lime sulphur, and also with an oil emulsion containing coconut fatty acid. These tests were made on March 18, and the scale was examined on April 18. The addition of weak lime sulphur or fatty acid to the oil emulsion evidently greatly increases its effectiveness, a kill of 100 per cent being obtained in all cases, except with the 2 per cent oil spray with fatty acid. The combination of oil emulsion and lime sulphur has been used by a few growers, apparently with good effect. In one case, 2,168 scales on a twig sprayed with this combination were examined, and none was alive. Unsprayed scales at that time averaged about 80 per cent alive. This combination is very apt to burn the foliage and should never be used except on dormant trees.

TABLE 5.—*Results of experiments with lubricating-oil emulsion in combination with weak lime sulphur and with fatty acid on the San Jose scale, Yakima, Wash., 1925*

[Approximately 1,000 scales examined in each test]

No.	Materials used	Dilution	Tests made	Scales dead	Control
		Per cent oil	*Number*	*Per cent*	*Per cent*
1	Lubricating-oil emulsion; [1] commercial lime sulphur, 1 gallon to 50 gallons	2	2	100.0	100.0
2	Lubricating-oil emulsion; [1] lime sulphur, 1 gallon to 25 gallons	2	2	100.0	100.0
3	Lubricating-oil emulsion; [1] lime sulphur, 1 gallon to 50 gallons	3	2	100.0	100.0
4	Fatty acid-oil emulsion [2]	2	1	99.7	99.4
5	Do	3	1	100.0	100.0
6	Do	4	1	100.0	100.0
7	Check	----	2	53.1	----

[1] See formula No. 2 (p. 9). [2] See formula No. 5 (p. 10.)

An orchard test was made in 1925 to compare the 4 per cent caseinate oil emulsion with the 4° Baumé lime sulphur. An examination of approximately 1,000 scales in each plat was made a month after spraying, and at harvest time the total fruit from six pear trees in each plat was examined, and the percentage of fruit that was free from scale was recorded. The oil gave better results, both in the percentage of scales killed and in the number of pears that remained free from scale. The first examination showed that 99.9 per cent of the oil-sprayed scales were dead and that only 84.1 per cent of those sprayed with lime sulphur were dead. At harvest time the pears were 96.1 and 88.8 per cent free from scale, respectively.

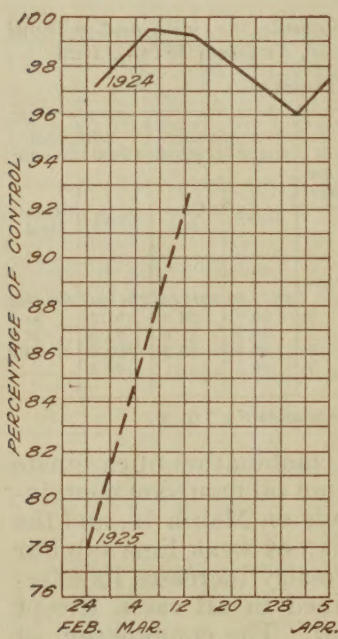

FIGURE 1.—Percentage control of the San Jose scale sprayed with 2 per cent heavy oil emulsion on various dates, Yakima, Wash., 1924–25

In comparing tests made on different dates, no consistent difference in toxicity could be observed. In 1924 tests were made about once a week from February 26, when the trees were entirely dormant, to April 4, when the fruit buds were showing. In 1925 two tests were made, one on February 24 and the other on March 13. The trees were dormant at both times. Figure 1 shows the results obtained with emulsions containing 2 per cent of heavy oils (No. 8 [4] in 1924 and No. 9 in 1925) on these dates. It is possible that wind or other weather conditions following the tests may have modified the results, but there is no evidence of increasing or decreasing toxicity as the season advanced.

SPRAYING EXPERIMENTS IN 1927

Experiments were made in 1927 to test the effect of several methods of emulsification, and also of the addition of Bordeaux mixture to the oil spray. (Table 6.) A commercial apple orchard was used that had been allowed to become rather uniformly infested with the San Jose scale. The spraying was done March 28 and 29 with a power spray outfit, using a pressure of 250 pounds. The examination of the sprayed scales was made April 29, and the fruit was examined October 4. As the owner of the orchard desired to obtain good control of the scale, it was not possible to leave any unsprayed trees, and the percentage of unsprayed scales that were dead was determined shortly before the spraying was done. On account of the heavy, uniform infestation in the orchard, there undoubtedly would have been a high percentage of infested fruit if the trees had not been sprayed. It is probable that most of the scales found on the fruit were brought into the trees during the summer by birds and by the wind.

[4] See p. 11.

TABLE 6.—*Results of experiments with lubricating-oil emulsions made with various emulsifiers, and in combination with Bordeaux mixture, on the San Jose scale, Yakima, Wash., 1927*

[Approximately 2,000 scales and 1,500 apples examined in each test]

No.	Material used [1]	Scales dead	Control	Apples scaly
		Per cent	*Per cent*	*Per cent*
1	Lubricating-oil (dark neutral [2]) emulsion (1 pound of spreader to 2 gallons of oil) [3]	100.0	100.0	0.38
2	Lubricating-oil (dark neutral [2]) emulsion (3 ounces of spreader to 2 gallons of oil) [3]	100.0	100.0	1.72
3	Same as 2, plus 6–6–50 Bordeaux	100.0	100.0	.57
4	Miscible oil [4] (dark neutral oil [2])	100.0	100.0	.47
5	Lubricating-oil (red engine [5]) emulsion (1 pound of spreader to 2 gallons of oil) [3]	100.0	100.0	.73
6	Lubricating-oil (red engine [5]) emulsion (3 ounces of spreader to 2 gallons of oil) [3]	100.0	100.0	.82
7	Same as 6, plus 6–6–50 Bordeaux	100.0	100.0	1.31
8	Miscible oil [4] (red engine oil [5])	100.0	100.0	1.19
9	Lime sulphur, 5° B., one application	92.3	77.2	.55
10	Lime sulphur, 5° B., two applications, 10 days apart	98.6	95.8	.91
11	Check	66.6		

[1] 4 per cent oil used in all of these tests.
[2] See specification No. 7 (p. 11).
[3] See formula No. 2a (p. 10).
[4] See formula No. 4 (p. 10).
[5] See specification No. 8 (p. 11).

These experiments do not indicate that any difference may be expected in commercial control from oil emulsions and from lime sulphur. Neither is there any indication that the type of emulsifier modifies the efficiency of the emulsion.

COMPOSITION OF SPRAY MATERIALS

The formulas used in preparing the oil emulsions tested are given below. The characteristics of the oils used are also given.

OIL EMULSIONS AND MISCIBLE OILS

No. 1.—Lubricating-oil emulsion (soap emulsifier). Made according to the Government formula.[5]

Oil	2 gallons.
Water	1 gallon.
Potash fish-oil soap	2 pounds.

These materials are heated until the soap is dissolved and the mixture comes to a boil. The mixture is then immediately pumped twice with a bucket pump or other suitable pump, using about 60 pounds pressure.

No. 2.—Lubricating-oil emulsion (casein emulsifier). Made according to the Missouri Agricultural Experiment Station formula.[6]

Oil	2 gallons.
Water	1 gallon.
Casein spreader	4 ounces.

The spreader is thoroughly mixed with the water, the oil is added, the mixture is stirred, and is then pumped three times with a bucket

[5] ACKERMAN, A. J. PRELIMINARY REPORT ON THE CONTROL OF THE SAN JOSE SCALE WITH LUBRICATING-OIL EMULSION. U. S. Dept. Agr. Circ. 263, 18 p., illus. 1923.
[6] BURROUGHS, A. M. Op. cit.

pump or other pump, the materials being forced through a spray nozzle at 150 to 200 pounds pressure.

No. 2a.—Same as formula 2, except that the quantity of spreader used was varied as indicated in Table 6.

No. 3.—Miscible oil.

	Per cent
Water	4.5
Dry soap	4.7
Cresol	5.6
Oil	85.2

The ingredients must be accurately measured by volume. The soap used is a potash fish-oil soap, such as that described in formula 10. The quantity of water in it must first be determined, and enough added to make up the amount called for above. The cresol (cresylic acid, 97–99 per cent, pale) is then added, and these ingredients are stirred, with gentle heat if necessary, until they are thoroughly mixed and uniformly clear. The oil is then added and thoroughly stirred in. The resulting miscible oil should be as clear as the pure oil, and no sediment should separate out other than the few impurities in the soap, nor should any free oil collect at the top. An oil of asphalt base must be used with this formula.

No. 4.—Miscible oil. Made according to the Washington State College formula.[7]

	Per cent
Potash fish-oil soap	5
Cresylic acid (technical cresol)	4
Oil	91

The ingredients are measured by volume. The fish-oil soap is dissolved in the cresylic acid, and the resulting "Cresoap" is then dissolved in the oil. The soap used should have the following specifications:

	Parts by weight
Fish oil	10
Caustic potash	2
Water	5

No. 5.—Lubricating oil-fatty acid emulsion. This formula was suggested by Siegler and Popenoe.[8]

Oil	gallons	2
Fatty acid	pounds	2¾
Caustic potash (commercial)	ounces	9
Kerosene	pints	2½
Water	gallons	2

The fatty acid used is a commercial mixture containing crude lauric acid, and is known as "double distilled coconut fatty acid." The caustic potash is dissolved in the water, and the fatty acid is melted and poured into the caustic solution. The oil is then added and the mixture heated to the boiling point. It is then removed from the fire, the kerosene is added, and the mixture is pumped twice to emulsify it.

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[7] MELANDER, A. L., SPULER, A., and GREEN, E. L. OIL SPRAYS; THEIR PREPARATION AND USE FOR INSECT CONTROL. Wash. Agr. Expt. Sta. Bul. 184, p. 19. 1924.

[8] SIEGLER, E. H., and POPENOE, C. H. SOME INSECTICIDAL PROPERTIES OF THE FATTY-ACID SERIES. Jour. Agr. Research (1924) 29: 259–261. 1925.

OILS AND SOAPS

No. 6.—Brown neutral oil.

Volatility (4 hours at 110° C.)	per cent	2.7
Viscosity (Saybolt at 100° F.)	seconds	116
Specific gravity at 20° C		0.922
Unsulphonated residue (38 N acid)	per cent	49

No. 7.—Dark neutral oil.

Viscosity	seconds	105
Unsulphonated residue (38 N acid)	per cent	75

No. 8.—Red engine oil.

Volatility	per cent	0.4
Viscosity	seconds	230
Specific gravity		0.921
Unsulphonated residue (38 N acid)	per cent	50

No. 9.—Eastern red engine oil.

Volatility	per cent	0.7
Viscosity	seconds	227
Specific gravity		0.903

No. 10.—Potash fish-oil soap.

	Per cent by volume
Water	22.5
Fatty anhydrides	66.0
Alkali (K_2O)	11.4

SUMMARY

Lubricating-oil emulsions have a number of advantages over lime sulphur when used for controlling the San Jose scale. The chief advantages are economy, greater ease in spraying thoroughly, and greater effectiveness against the eggs of the red spiders, tree hoppers, and the fruit-tree leaf roller, and against aphids.

The danger of injury to dormant trees from oil sprays, if properly made and used at the right time, is very slight. These sprays must be used in the spring before the bud scales separate. Injury may result if they are used later than this, but no injury has resulted from low temperatures following sprays applied in the spring.

In order to obtain a satisfactory control of the San Jose scale in the Pacific Northwest, lubricating-oil sprays must be used at a dilution containing 4 per cent of oil. This dilution only allows a fraction of 1 per cent of the scale to live, while complete mortality may be obtained with 6 and 8 per cent dilutions. It is probable that the 3 per cent dilution would be effective if the infestation of the scale were very light. Dilutions containing only 2 per cent of oil do not give satisfactory control.

When used at 3 or 4 per cent there is practically no difference in the effectiveness of oils of the red engine and of the brown neutral types, even though the latter oils are lighter. Oils with a sulphonation test of 50 to 70 per cent may be used safely. The three types of oil sprays tested—the cold-mixed caseinate oil emulsion, the boiled emulsion, and the miscible oil—gave very similar results.

The boiled emulsion, made with soap, is readily broken down in hard water, and its use can not be recommended in the Pacific North-

west unless soft water is available. The miscible oil mixes very well with most hard waters. The boiled emulsion and caseinate emulsion may be made very easily, but the manufacture of miscible oil should not be attempted by the grower unless a cresol-soap emulsifier can be obtained. Satisfactory miscible oils and oil emulsions are on the market which may be used in place of the homemade materials, and in most cases these will be safer and more economical.

The addition of casein spreader to the diluted caseinate emulsion apparently neither increases nor decreases its effectiveness against the San Jose scale.

The addition of weak lime sulphur to the caseinate emulsion increases its toxicity, a complete mortality resulting from a 2 or 3 per cent oil emulsion to which this has been added. This combination should be used only on dormant trees, as it is very likely to burn the foliage. An oil emulsion containing coconut fatty acid is also evidently more toxic than one without.

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